JC376 U.S. PTO 03/23/99

JC612 U.S. PTO 09/274501 03/23/99

Express Mail Label No. EM400950409US

UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 CFR 1.53(b))	Attorney Docket No.	MIT-106
	First Named Inventor	Michael Mermelstein
	Title	OPTICAL SYNTHETIC APERTURE ARRAY

APPLICATION ELEMENTS	ADDRESS TO: **Box Patent Application Assistant Commissioner for Patents Washington, D.C. 20231**
1. ☒ Fee Transmittal Form	**ACCOMPANYING APPLICATION PARTS**
2. ☒ Specification and Drawings [Total Pages 23] ☒ - Specification - (11 pages) ☒ - Claims - (5 pages) ☒ - Abstract - (1 page) ☒ - Sheets of Drawings - (6 sheets) ☐ Formal ☒ Informal	7. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney 8. ☐ English Translation Document *(if applicable)* 9. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
3. ☒ Oath or Declaration [Total Pages 3] a. ☒ Newly executed (original) b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)* *[Note Box 4 below]*	10. ☐ Preliminary Amendment ☐ Drawings [Total Sheets] ☐ Letter to Official Draftsperson Including Drawings [Total Pages] 11. ☒ Return Receipt Postcard
4. ☐ Incorporation by Reference (usable if Box 3b is checked) The entire Disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 3b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.	12. ☐ Small Entity Statement(s) ☐ Statements filed in prior application, (Status still proper and desired) 13. ☐ Certified Copy of Priority Document(s)
5. ☐ Microfiche Computer Program *(Appendix)*	14. ☐ Deletion of Inventor(s) Signed statement attached deleting inventor(s) named in the prior application.
6. ☐ Nucleotide and/or Amino Acid Sequence Submission ☐ Computer Readable Copy ☐ Paper Copy (identical to computer copy) ☐ Statement verifying identify of above copies	15. ☒ Patent Application Data Entry Form 16. ☐ Other:

17. ☐ **If a CONTINUING APPLICATION,** check appropriate box and supply the requisite information:
☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application Serial No. _____/_____.
Priority to the above application(s) is claimed under 35 U.S.C. 120.
Prior application information: Examiner: _____. Group/Art Unit: _____.

18. ☐ **Priority - 35 U.S.C. 119**
☐ Priority of application Serial No. __________ filed on _____ in_____ is claimed under 35 U.S.C. 119.
☐ The certified copy has been filed in prior U.S. application Serial No. _____/_____ on _____.
☐ The certified copy will follow.

CORRESPONDENCE ADDRESS	**SIGNATURE BLOCK**
Direct all correspondence to: Patent Administrator Testa, Hurwitz & Thibeault, LLP High Street Tower 125 High Street Boston, MA 02110 Tel. No.: (617) 248-7000 Fax No.: (617) 248-7100	Respectfully submitted, Date: March 23, 1999 Reg. No. 41,047 Tel. No.: (617) 248-7074 Fax No.: (617) 248-7100 William G. Guerin Attorney for Applicant Testa, Hurwitz & Thibeault, LLP High Street Tower 125 High Street Boston, MA 02110

462WGG5473/112.755272-1

Inventor Information

Inventor One Given Name ::	Michael
Family Name ::	Mermelstein
Postal Address Line One ::	174 Brookline Street, Apt. 3
City ::	Cambridge
State/Province ::	Massachusetts
Country ::	United States
Postal or Zip Code ::	02139
City of Residence ::	Cambridge
State/Prov. of Residence ::	Massachusetts
Country of Residence ::	United States
Citizenship ::	United States of America

Correspondence Information

Correspondence Customer Number ::021323

Application Information

Title Line One ::	Optical Synthetic Aperture Array
Title Line Two ::	
Total Drawing Sheets ::	6
Formal Drawings ::	N
Application Type ::	Utility
Docket Number ::	MIT-106 (5473/112)
Licensed - U S Government Agency ::	Defense Advanced Research Projects Agency (DARPA)
Contract Number ::	F30602-97-2-0106
Grant Number ::	
Secrecy Order in Parent Application ::	

Representative Information

Representative Customer Number :: 021323

Continuity Information

This application is a ::
> Application One ::
Filing Date ::
Patent Number ::

462WGG5473/112.755797-1

Express Mail Label No. EM400950409US

ATTORNEY DOCKET NO. MIT-106
(5473/112)

OPTICAL SYNTHETIC APERTURE ARRAY

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made with government support under Contract No. F30602-97-2-0106 awarded by the Defense Advanced Research Projects Agency (DARPA). The government may have certain rights in the invention.

FIELD OF THE INVENTION

The invention relates to the field of synthetic aperture arrays and more specifically to the field of optical synthetic aperture arrays.

BACKGROUND OF THE INVENTION

High resolution projection systems are used to project an image of a mask onto the surface of a semiconductor wafer coated with a chemical photoresist during the fabrication of semiconductor circuits. Exposed regions of photoresist within the image of the mask are chemically altered and react differently to subsequent chemical or physical treatment of the wafer than unexposed regions. A series of masks and intervening treatments are used to form layers on the wafer having the required electronic structures.

The masks used in the process are expensive and time consuming to produce. Further changes required in the circuitry after the mask is produced typically require a new mask to be created. The complex optical systems used in the process are also expensive and require significant maintenance. High numerical aperture lenses have small depths of field and are limited in contrast at higher spatial frequencies. The demanding requirements of the semiconductor industry for higher resolution, contrast,

depth of field and optical efficiency are coupled with a desire to minimize distortion. Physical constraints inherent in projection lens systems will limit further performance improvements.

The present invention overcomes the problems associated with the use of physical masks and lenses.

SUMMARY OF THE INVENTION

The invention relates to a synthetic aperture system for producing a non-periodic pattern in a region of overlap. The system includes a source of electromagnetic radiation producing a plurality of electromagnetic beams, a plurality of beam controllers positioned to receive a respective one of the plurality of electromagnetic beams and direct the respective electromagnetic beam into the region of overlap and a system controller in electrical communication with each of the plurality of the beam controllers. Each beam controller controls at least one of the phase, amplitude and polarization of a respective one of the plurality of electromagnetic beams in response to control signals from the system controller. The result is a non-periodic pattern formed within the region of overlap by the interference of a plurality of electromagnetic beams in response to the control signals from the system controller.

In one embodiment the plurality of sources of electromagnetic radiation includes a laser producing an electromagnetic beam and a beam splitter device positioned to receive the electromagnetic beam and produce a plurality of electromagnetic sources therefrom. In one embodiment one of the beam controllers includes an acousto-optic modulator.

In another embodiment the system includes a field stop adjacent to the image plane. The field stop limits a spatial extent of the non-periodic pattern. In still yet another embodiment the system further includes an apodizing element for at least one of the plurality of electromagnetic beams. The apodizing element limits a spatial extent of the at least one electromagnetic beam.

The invention also relates to a method for producing a non-periodic pattern in a region of overlap. The method includes the steps of providing a plurality of electromagnetic beams, directing the plurality of electromagnetic beams into the region of overlap, and modulating at least one of the phase, amplitude and polarization of at least one of the plurality of electromagnetic beams to thereby form a predetermined non-periodic pattern on the image plane by the interference of the plurality of electromagnetic beams.

In one embodiment the step of modulating at least one of the phase, amplitude and polarization of each of the plurality of electromagnetic beams includes the steps of providing an acoustic-optic modulator and acoustic-optically modulating the electromagnetic beam. In another embodiment the step of providing the plurality of electromagnetic beams includes the steps of providing a source of an electromagnetic beam and splitting the electromagnetic beam into a plurality of electromagnetic beams.

In another embodiment the method further includes the steps of providing a substrate, providing a layer of photoresist on the substrate, and exposing the photoresist to the non-periodic pattern. In yet another embodiment the method further includes repeating the step of modulating to generate a predetermined pattern in the layer of

photoresist. In still another embodiment the method further includes the step of calibrating the interference pattern prior to forming the non-periodic pattern. In one embodiment the step of calibrating the interference occurs during the generation of the non-periodic pattern. In still yet another embodiment the method includes the step of apodizing the non-periodic pattern.

The invention also relates to a system and a method that can be used to replace the lens, the mask and the mask illuminator of conventional lithography systems with a discrete set of controllable beam sources. Highly reliable solid-state modulators can be used to control the amplitudes and phases of the beams. The system and method are scaleable to wavelength regimes for which high numerical aperture lenses are not feasible. Further advantages include the optimum use of beam energy, excellent control of contrast and a large depth of field.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will become apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings, in which:

Fig. 1 is a highly schematic diagram of an embodiment of a system constructed in accordance with the invention;

Figs. 2 a and b are simulated intensity profiles depicting the effect of changing parameters in a fifteen beam optical synthetic aperture array system;

Figs. 3 a-c is a simulation of an intensity profile resulting from the combination of two projection primitives (Figs. 3 a and b) to obtain a desired projection image (Fig. 3c);

Fig. 4 is a flowchart depicting the steps required in one embodiment of the invention to generate a projection primitive;

Figs. 5 a-c is a contour intensity plot resulting from the combination of two projection primitives (Figs. 5 a and b) to obtain a desired projection image (Fig. 5c);

Figs 6 a and b are tables of the amplitude and phase for each of the fifteen beams which were used to create the projection primitives shown in Figs. 5 a and b, respectively;

Fig. 7 is a highly schematic diagram of an embodiment of the system of the invention utilizing acoustic-optical modulators for modifying the phase of the optical radiation; and

Fig. 8 is a schematic diagram of an embodiment of the system using a calibration device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Fig. 1 an optical synthetic aperture array system includes a number of optical radiation sources 10 (a-e), each of which is controlled by a controller 14 to produce an optical beam 18 (a-e) having a predetermined intensity, phase and polarization. The beams 18 (a-e) are directed toward the surface of a wafer 20 such that the beams 18 (a-e) overlap and form an interference pattern at the surface of the wafer 20. The width of the beams 18 or of an aperture or apodizing element (not shown) above the wafer 20 limits the region of overlap to a size appropriate to the number of beams used to form the pattern.

Referring to Fig. 2a, an intensity profile of an interference pattern simulated as being formed from fifteen beams is depicted. The peak of the radiation intensity is roughly at the center of the graph. By changing the relative phase and intensities of the fifteen beams, a new pattern is formed Fig. 2b in which the peak radiation pattern is shifted to the left. Thus by adjustment of the relative phase and intensity of the beams from a number of sources an arbitrary pattern may be generated. Although only five radiation sources, generally 10, are shown for clarity any number of sources can be used. In one embodiment fifteen sources 10 are used.

The wafer 20 is coated with a positive photoresist 24 which reacts upon exposure to optical radiation to form a material which is removed in subsequent wafer treatment as is practiced using conventional lithography known to the art. Alternatively, the wafer 20 is coated with a negative photoresist 24 which reacts upon exposure to optical radiation to form a material which resists subsequent wafer treatment. Once the wafer 20 has been exposed to the beam radiation for a period of time, the intensity and phase of the radiation beams, generally 18, is changed by the controller 14, and the resist coated wafer 20 is exposed again to the new interference pattern which is thereby formed. In this way the desired exposure pattern may be constructed from multiple exposures of the wafer 20 to a number of basic or primitive interference patterns.

Figs. 3a and 3b depict the intensity profiles of two projection primitives which are combined through multiple exposures to form a desired pattern (Fig. 3c) on the chemical resist 24. In this case the formed pattern is a rectangle having a 3:10 aspect ratio. In this example the two primitives are actually the same primitive shifted in space. Other

formed patterns can be generated using selected shapes from a shape library. The desired pattern is analyzed to determine the smallest set of generalized shapes stored in the library which can be used to represent the pattern. Integrating the exposures necessary for each shape yields the desired pattern.

Individual shapes can be rotated or translated as required by determining the phase and amplitude changes equivalent to the corresponding displacement of the wafer 20 relative to the beams for each of the projection primitives used to create the shape. Translation of a projection primitive can be accomplished by adjusting the phases of the beams according to the beam's coordinates with respect to the desired axis of translation. The result is conceptually equivalent to that achieved by tilting the projector as a unit relative to the wafer 20.

A circular arrangement of beams can provide advantages including, for example, a large depth of field which exists throughout the region of overlap. This depth of field is large in comparison to that achievable with convention imaging with lens systems. In addition, the projection primitive can be easily rotated multiples (n) of 360/n degrees, where n is the number of beams and the beams are arranged with rotational symmetry. In such a case, the phase and amplitude of each beam is simply assigned to the phase and amplitude of the correct beam ahead of or before it, depending upon whether the rotation is clockwise or counterclockwise. Integrating the exposures necessary for each shape yields the desired pattern.

In some instances there may be no satisfactory combination of projection primitives in the library for a particular shape and, therefore, determination of a new set

of exposures corresponding to one or more new projection primitives is required. Under these circumstances a penalty/reward function (PR function) based on the desired pattern is utilized. The PR function is designed to calculate a figure of merit indicating how well a particular combination of phase and amplitude values represents the desired pattern. The function is positively influenced for energy predicted to lie within the desired shape. The function, however, imparts a disproportionately greater negative influence on the figure of merit for exposure dose predicted to lie outside the desired shape. For example, the function can integrate dose over the desired shape area and multiply the result by a small positive value to generate a positive product. This function then integrates dose over a bounded area (e.g., a portion of the wafer surface area) that surrounds the desired shape area and multiplies the result by a large negative value to generate a negative product. The figure of merit is the sum of the negative and positive products. The unbalanced sensitivity of this function is due to the ability to add exposure dose when insufficient exposure results inside the desired shape and the inability to remove unwanted exposure dose for regions outside the desired shape. An initial guess of amplitude and phase values for the beams is made and the figure of merit is calculated. At least one amplitude or phase value is then changed and a new figure of merit is calculated. This process is iterated in a controlled manner so that sensitivities to amplitude and phase values can be utilized and an optimum is determined. Most lithographic patterns are made up of a small set of shapes such as rectangles, circles, donuts, dots, dot combinations and rectangle combinations. Once these shapes are optimized, it would not generally be necessary to compute new projection primitives.

In more detail, Fig. 4 depicts a flowchart of an embodiment of a method for generating an unknown projection primitive. First a library of projection primitives is searched to determine if an acceptable projection primitive exists (step 100), and if one is found, it is used (step 104). If one is not found a penalty/reward function is generated (step 108) having the characteristics discussed above. An initial guess is made for the command vector, a set of amplitudes and phases for the optical beams used in the projection beams, which will cause the penalty reward function to reach an extreme (step 112). The extreme is either a maximum or minimum, depending on whether the penalty/reward function is constructed so as to minimize or maximize upon finding the optimum vector. Using this command vector a dose simulation is performed (step 116), the penalty/reward function is evaluated (step 120) and a determination is made as to whether it is an optimum (step 124).

The determination of local extreme in one embodiment is accomplished using a hill climbing algorithm. According to this algorithm if the command vector does not result in a local extreme, then the command vector is modified (step 128) and the process is repeated (step 116). To modify the command vector initially a new vector is simply selected, for example a set of random numbers, and evaluated. However, once a number of penalty/reward function evaluations have occurred, an informed guess can be made by looking at the gradient of the penalty/reward function as a function of the various parameters. One way of forming such an informed guess command vector is using a Nelder-Mead simplex search method. The best local extreme is then used to form the desired projection primitive and its sufficiency evaluated (step 132). If the primitive is

sufficient it is used (step 136) and, if not, the calculated projection primitive is subtracted from the desired projection primitive to provide a new desired pattern (step 140), and the process is repeated (step 100).

Figs. 5a and 5b depict a contour intensity plot for two primitives which when combined form a rectangle as shown in the contour intensity plot in Fig. 5c. In use, a wafer is exposed to the first primitive (Fig. 5a) and then subsequently exposed to the second primitive (Fig. 5b). The chemical photoresist 24 integrates the intensity from the two images which results in the rectangle shown in Fig. 5c. Figs. 6a and 6b list the intensity (amplitude) and phase for each of the fifteen beams used to create the primitives shown in Figs. 5a and 5b, respectively.

Because an interference pattern generated by the numerous sources may have a spatial extent beyond the actual portion of the pattern of interest, it is occasionally necessary to remove the unwanted portion of the pattern. Referring again to Fig. 1, in one embodiment one mechanism for limiting the spatial extent of the interference pattern is to place an aperture 44 (shown in phantom as a hole 44 in a plate 40) in the beam path to physically limit the extent of the interference pattern at the wafer surface.

In the embodiment shown in Fig. 1 the sources 10 are each controlled directly by controller 14 to achieve the desired intensity and phase of each beam 18. In an alternative embodiment shown in Fig. 7 the phase and intensity of each of the beams 18 is determined by the controller 14. The phase and intensity are changed by a modulator 50 a and d such as an acoustic-optical modulator placed in the path of each beam 18 between the source 10 and the wafer 20 according to parameters set by the controller 14. The

embodiments shown in Fig. 1 and Fig. 7 can be part of a system which provides for rotation and translation of the wafer 20. In addition, groups of sources 10 and modulators 50 can be utilized. The fields of view of the groups can be appended to generate large patterns.

Due to mechanical limitations and the high sensitivity of the exposure pattern to the relative phases of the beams, calibration of the synthetic aperture lithographic system is generally required. In the embodiment shown in Fig. 8 a feed-forward control configuration for calibration is shown. During calibration the wafer 20 is removed from its normal exposed position 60 (shown in phantom) and a microscope objective 62 images a portion of the interference pattern onto a CCD camera for a specific set of control parameters. Multiple interference patterns can be used. For example, each calibration pattern can be an interference pattern generated by a single beam pair. A processor 66 and associated memory module 68 are used to analyze the generated calibration patterns based on the known system response and compensate for the phase and/or amplitude offsets in future projections. Alternatively, a feedback configuration can be used for applications when the system is not sufficiently stable for the feed-forward calibration. A sensing system for continuously observing the relative phases and/or amplitudes of the beams during projection can be used to correct for variations as they occur.

While the invention has been particularly shown and described with reference to specific preferred embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

CLAIMS

What is claimed is:

1. A synthetic aperture system for producing a spatially non-periodic pattern in a region of overlap comprising:

a source of electromagnetic radiation producing a plurality of electromagnetic beams;

a plurality of beam controllers positioned to receive a respective one of said plurality of said electromagnetic beams and direct said respective electromagnetic beam into said region of overlap; and

a system controller in electrical communication with each of said plurality of said beam controllers,

wherein each beam controller controls at least one of the phase, amplitude and polarization of a respective one of said plurality of electromagnetic beams in response to control signals from said system controller, and

wherein a spatially non-periodic pattern is formed within said region of overlap by the interference of said plurality of electromagnetic beams in response to said control signals from said system controller.

2. The system of claim 1 further comprising a source controller in electrical communication with said system controller and said source of electromagnetic radiation wherein said source controller controls the amplitude of each of said plurality of electromagnetic beams as a function of time in response to said control signals from said system controller.

3. The system of claim 1 wherein said source of electromagnetic radiation comprises:

a laser producing an electromagnetic beam; and

a beam splitter device positioned to receive said electromagnetic beam and produce said plurality of electromagnetic beams therefrom.

4. The system of claim 1 wherein one of said beam controllers comprises an acoustic diffractive device.

5. The system of claim 4 wherein one of said beam controllers comprises an acousto-optic modulator.

6. The system of claim 1 further comprising a field stop adjacent to said region of overlap wherein said field stop limits a spatial extent of said spatially non-periodic pattern.

7. The system of claim 1 further comprising an apodizing element for at least one of said plurality of electromagnetic beams wherein said apodizing element limits a spatial extent of the at least one electromagnetic beam.

8. The system of claim 1 further comprising a receiver to receive said spatially non-periodic pattern.

9. The system of claim 8 wherein said receiver comprises a photosensitive chemical receiver.

10. The system of claim 8 wherein said receiver receives a plurality of said spatially non-periodic patterns.

11. A method for producing a spatially non-periodic pattern in a region of overlap comprising the steps of:

providing a plurality of electromagnetic beams;

directing said plurality of electromagnetic beams into said region of overlap; and

modulating at least one of the phase, amplitude and polarization of at least one of said plurality of electromagnetic beams to thereby form a spatially non-periodic pattern in said region of overlap by the interference of said plurality of electromagnetic beams.

12. The method of claim 11 wherein the step of modulating at least one of the phase, amplitude and polarization of said at least one of said plurality of electromagnetic beams comprises the steps of:

providing an acoustic diffractive modulator; and

modulating said electromagnetic beam using said acoustic diffractive modulator.

13. The method of claim 11 wherein said step of providing said plurality of electromagnetic beams comprises the steps of:

providing a source of an electromagnetic beam; and

splitting said electromagnetic beam into a plurality of electromagnetic beams.

14. The method of claim 11 further comprising the steps of:

providing a substrate;

providing a layer of photoresist at said substrate; and

exposing said photoresist to said spatially non-periodic pattern.

15. The method of claim 14 further comprising repeating said steps of modulating and exposing to generate a predetermined pattern in said layer of photoresist.

16. The method of claim 11 further comprising the step of calibrating said interference prior to forming said spatially non-periodic pattern.

17. The method of claim 11 further comprising the step of calibrating said interference during generation of said spatially non-periodic pattern.

18. The method of claim 11 further comprising the step of apodizing said spatially non-periodic pattern.

19. A synthetic aperture system for producing a spatially non-periodic pattern in a region of overlap comprising:

a source of electromagnetic radiation producing an electromagnetic beam;

a beam controller positioned to receive said electromagnetic beam and generate a plurality of output beams; and

a system controller in electrical communication with said beam controller,

wherein said beam controller controls at least one of the phase, amplitude and polarization of at least one of said output beams in response to control signals from said system controller, and

wherein a spatially non-periodic pattern is formed within said region of overlap by the interference of said plurality of output beams in response to said control signals from said controller.

20. The synthetic aperture system of claim 19 wherein said beam controller further comprises a source controller in electrical communication with said source of electromagnetic radiation, said source controller controlling the amplitude of said electromagnetic beam produced by said source as a function of time in response to control signals from said system controller.

21. The synthetic aperture system of claim 19 further comprising at least one beam director positioned to receive a respective one of said plurality of output beams and direct said respective output beam into said region of overlap.

ABSTRACT

A synthetic aperture system for producing a non-periodic pattern in a region of overlap. The system includes a source of electromagnetic radiation producing a plurality of electromagnetic beams, a plurality of beam controllers positioned to receive a respective one of the plurality of electromagnetic beams and direct the respective electromagnetic beam into the region of overlap; and a system controller in electrical communication with each of the plurality of the beam controllers. Each beam controller controls at least one of the phase, amplitude and polarization of a respective one of the plurality of electromagnetic beams in response to control signals from the system controller. The result is a non-periodic pattern formed within the region of overlap by the interference of a plurality of electromagnetic beams in response to the control signals from the system controller.

The invention also relates to a method for producing a non-periodic pattern in a region of overlap. The method includes the steps of providing a plurality of electromagnetic beams, directing the plurality of electromagnetic beams into the region of overlap, and modulating at least one of the phase, amplitude and polarization of at least one of the plurality of electromagnetic beams to thereby form a predetermined non-periodic pattern in the region of overlap by the interference of the plurality of electromagnetic beams.

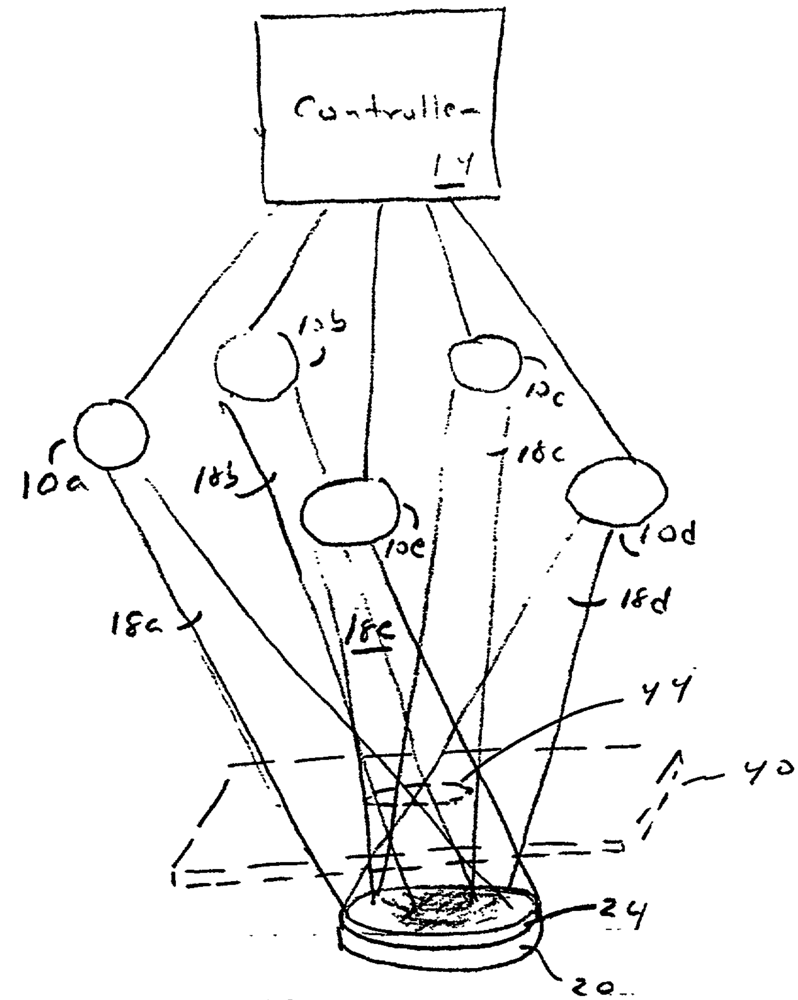

Controller
14
10a
10b
10c
10d
10e
18a
18b
18c
18d
18e
44
40
24
20

Fig 1

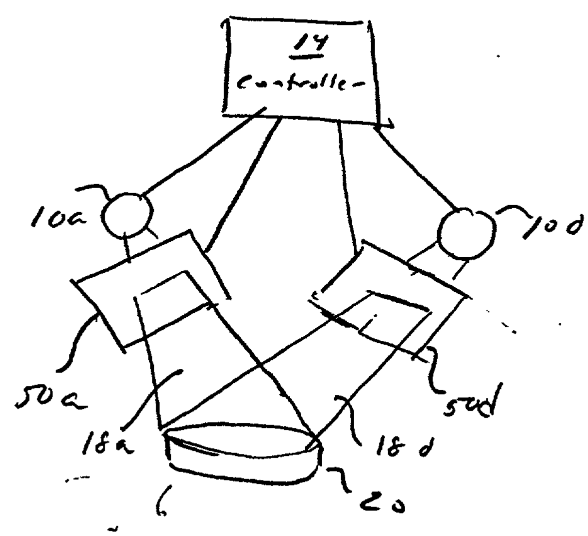

14
controller
10a
10d
50a
50d
18a
18d
20

Fig 7

Fig 2a

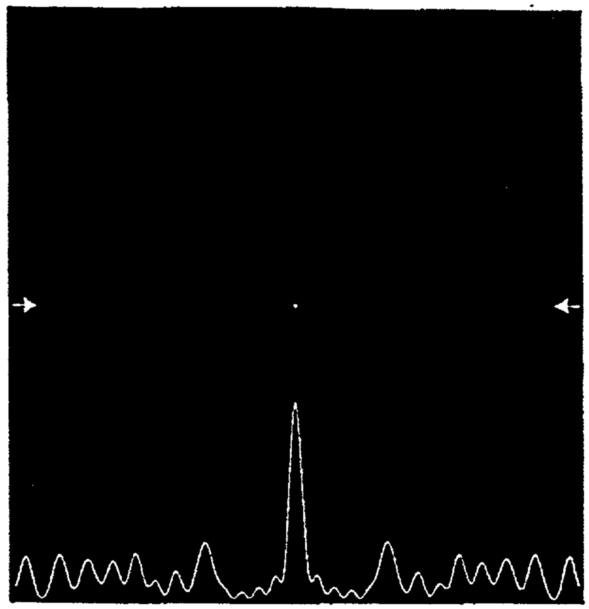


Fig 2b

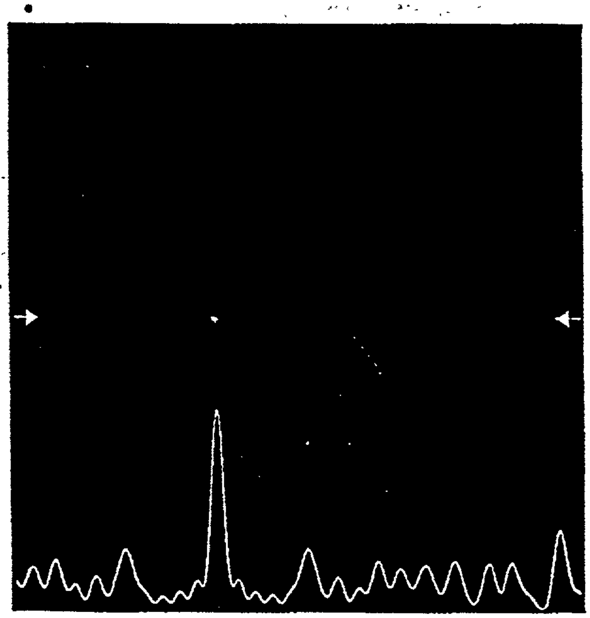


Fig 3a

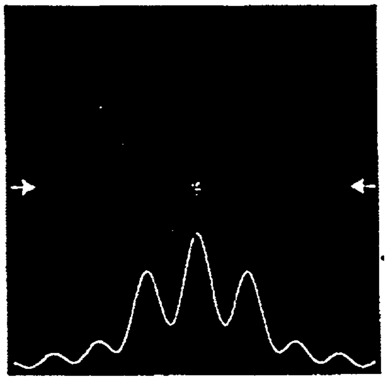


Fig 3b

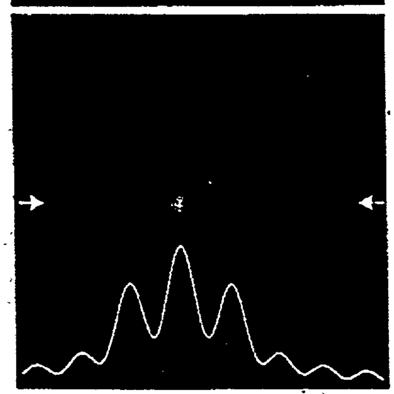
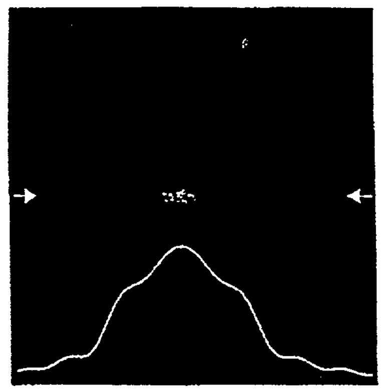


Fig 3c



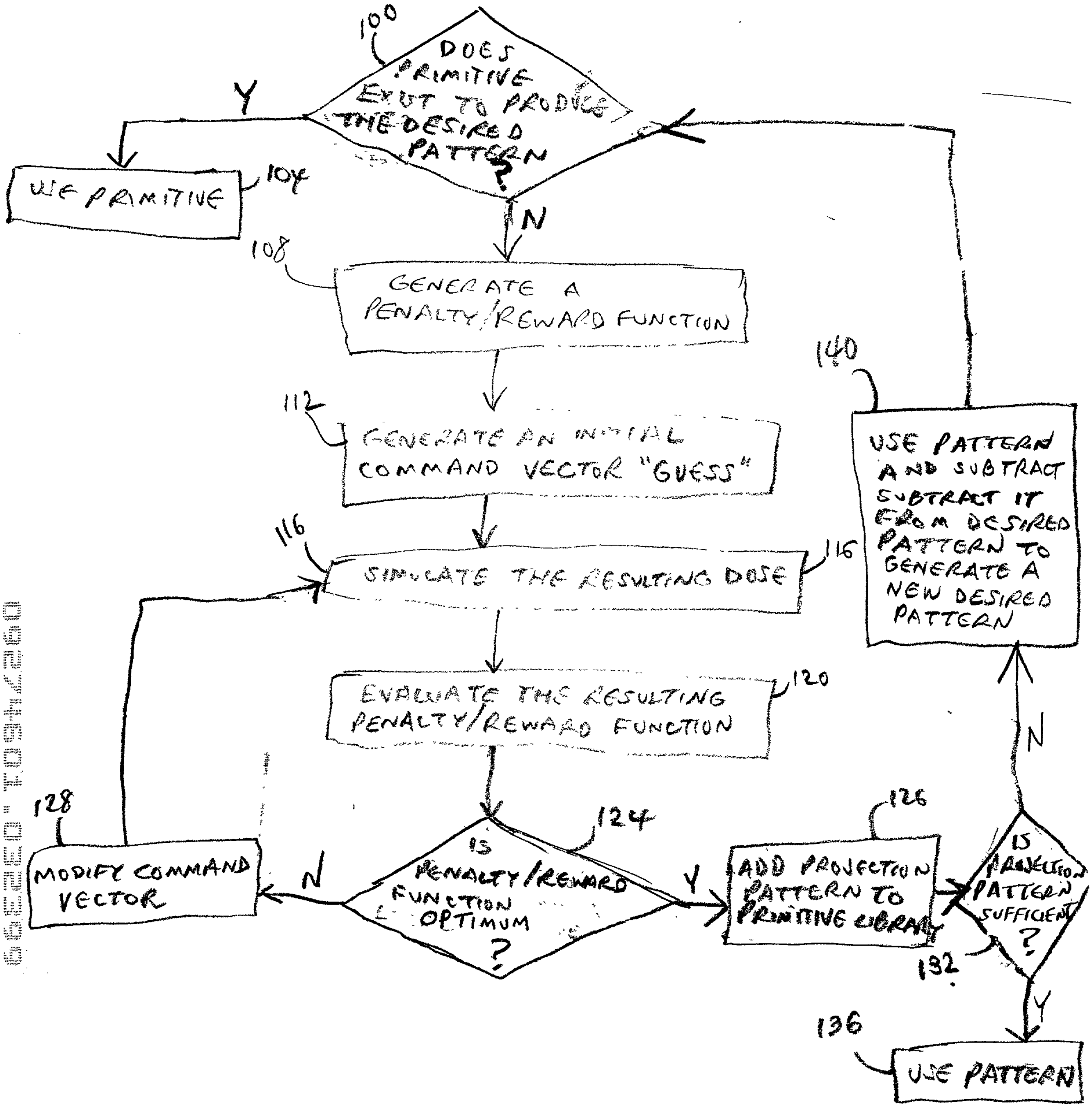

100
DOES PRIMITIVE EXIST TO PRODUCE THE DESIRED PATTERN ?
Y
USE PRIMITIVE
104
N
108
GENERATE A PENALTY/REWARD FUNCTION
112
GENERATE AN INITIAL COMMAND VECTOR "GUESS"
116
SIMULATE THE RESULTING DOSE
116
EVALUATE THE RESULTING PENALTY/REWARD FUNCTION
120
128
MODIFY COMMAND VECTOR
N
124
IS PENALTY/REWARD FUNCTION OPTIMUM ?
Y
126
ADD PROJECTION PATTERN TO PRIMITIVE LIBRARY
IS PROJECTION PATTERN SUFFICIENT ?
132
N
140
USE PATTERN AND SUBTRACT SUBTRACT IT FROM DESIRED PATTERN TO GENERATE A NEW DESIRED PATTERN
Y
136
USE PATTERN

FIG. 4

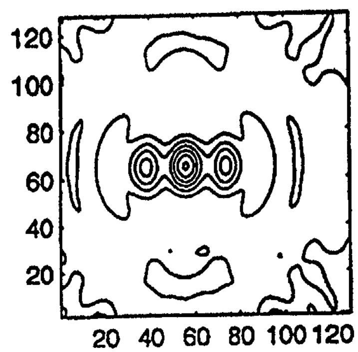


Fig 5a

Amplitudes	Phases
3757	1.634
2722	1.167
520	0.625
420	2.738
1324	5.340
2769	4.771
3006	4.539
3014	4.528
2758	4.836
1308	5.394
416	3.071
536	0.494
2726	1.202
3749	1.649
3706	1.827

Fig 6a

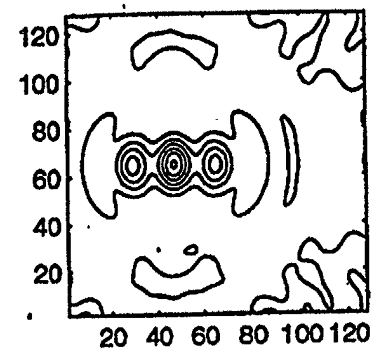


Fig 5b

Amplitudes	Phases
3757	3.278
2722	2.371
520	1.181
420	2.550
1324	4.440
2769	3.315
3006	2.779
3014	2.767
2758	3.380
1308	4.494
416	2.882
536	1.051
2726	2.407
3749	3.293
3706	3.627

Fig 6b

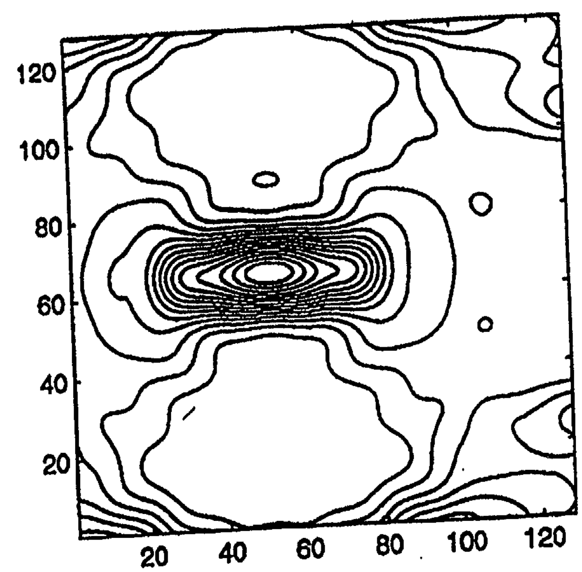


Fig 5c

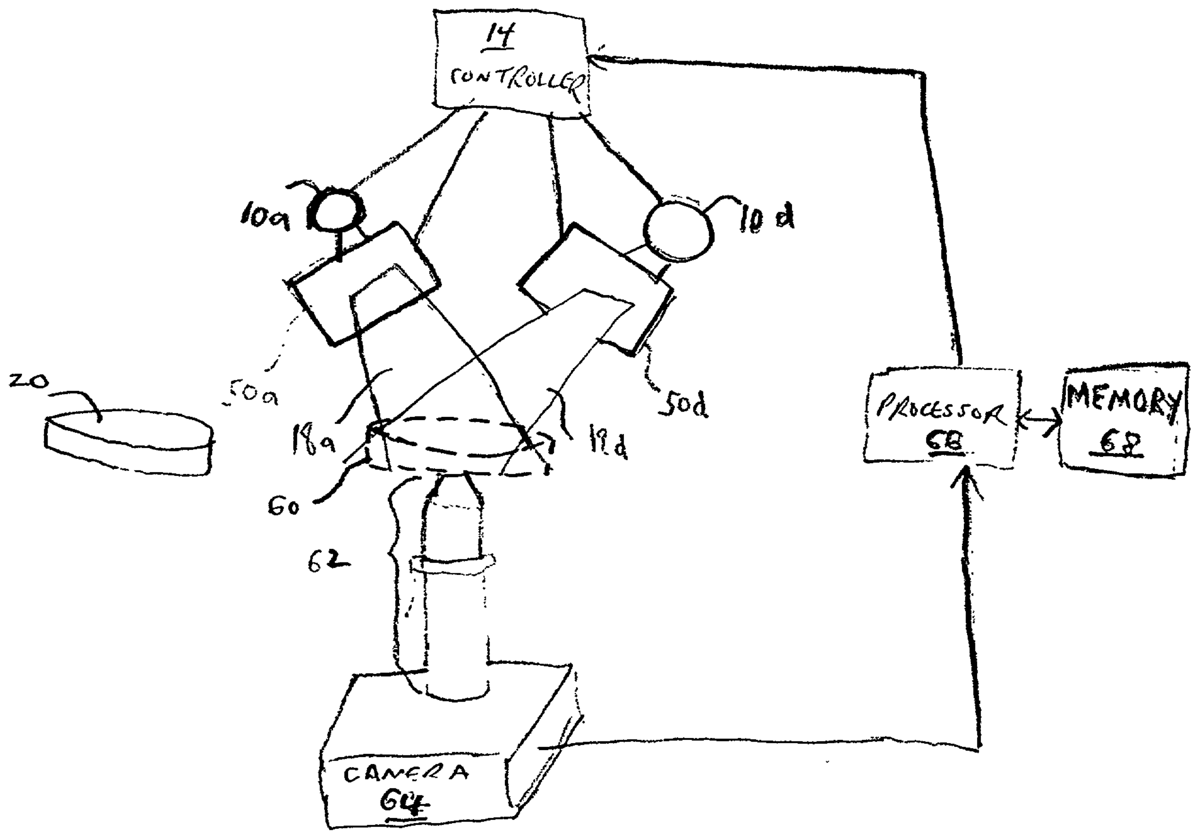

14
CONTROLLER
10a
10d
20
50a
50d
18a
18d
60
62
PROCESSOR
68
MEMORY
68
CAMERA
64

Fig. 8

Express Mail Label No. EM400950409US

DECLARATION AND POWER OF ATTORNEY FOR UTILITY OR DESIGN PATENT APPLICATION	Attorney Docket No.	MIT-106
	First Named Inventor	Michael Mermelstein
☒ Declaration Submitted with Initial Filing	***COMPLETE IF KNOWN***	
☐ Declaration Submitted after Initial Filing (surcharge 37 CFR 1.16(e) required)	Application Serial Number	Not Yet Assigned
	Filing Date	Herewith
	Group Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

OPTICAL SYNTHETIC APERTURE ARRAY

(Title of the Invention)

the specification of which

☒ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ______ as United States Application Serial Number or PCT International Application Number ______ and was amended on (MM/DD/YYYY) ______ *(if applicable).*

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet attached hereto.

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Serial Number(s)	Filing Date (MM/DD/YYYY)	
		☐ Additional provisional application serial numbers are listed on a supplemental priority data sheet attached hereto.

DECLARATION - Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c), of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Serial Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet attached hereto.

As a named inventor, I hereby appoint the following registered practitioners to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number → *Place Customer Number Bar Code Label Here*

OR

☒ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Steven M. Bauer	31,481	Kurt W. Lockwood	40,704
Isabelle A.S. Blundell	43,321	Marianne McLaughlin	42,870
Michael H. Brodowski	41,640	Thomas C. Meyers	36,989
Jennifer A. Camacho	P-43,526	Joseph B. Milstein	42,897
Joseph A. Capraro, Jr.	36,471	Ronda P. Moore	P-44,244
Jerrie L. Chiu	41,670	Edmund R. Pitcher	27,829
John J. Cotter	38,116	Kurt Rauschenbach	40,137
Jennifer L. Dupre	41,722	Michael A. Rodriguez	41,274
John V. Forcier	42,545	Michael J. Schmelzer	43,093
Duncan A. Greenhalgh	38,678	J. Scott Southworth	39,382
William G. Guerin	41,047	Christopher W. Stamos	35,370
Ira Heffan	41,059	Robert J. Tosti	35,393
Danielle L. Herritt	P-43,670	Thomas A. Turano	35,722
Elizabeth E. Kim	43,334	Michael J. Twomey	38,349
Douglas J. Kline	35,574	Christine C. Vito	39,061
John D. Lanza	40,060	Patrick R.H. Waller	41,418
Timothy P. Linkkila	40,702		

☐ Additional registered practitioners named on supplemental Registered Practitioner Information sheet attached hereto.

Direct all correspondence to:

Patent Administrator
Testa, Hurwitz & Thibeault, LLP
High Street Tower
125 High Street
Boston, MA 02110
Tel. No.: (617) 248-7000
Fax No.: (617) 248-7100

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Michael				**Mermelstein**			
Inventor's Signature	Michael Mermelstein			Date	~~5 March 99~~ 5 March 99		
Street Address	**174 Brookline Street, Apt. 3**			Citizenship	**USA**		
	City	**Cambridge**	State	**MA**	Zip	**02139**	Country **USA**
Post Office Address	**174 Brookline Street, Apt. 3**						
	City	**Cambridge**	State	**MA**	Zip	**02139**	Country **USA**

☐ Additional inventors are being named on the _____ supplemental Additional Inventor(s) sheet(s) attached hereto.

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature				Date			
Street Address				Citizenship			
	City		State		Zip		Country
Post Office Address							
	City		State		Zip		Country

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature				Date			
Street Address				Citizenship			
	City		State		Zip		Country
Post Office Address							
	City		State		Zip		Country